AD-E 900 3C

NWC TP 6098

(12)

AD A139928

Aircrew Gliding Escape System (AGES) Exploratory Development Investigation of Aircrew Emergency Escape Ram-Air Inflated, Flexible Wing

by
Jon T. Matsuo
and
Manley C. Butler, Jr.
Aerosystems Department

SEPTEMBER 1983

**NAVAL WEAPONS CENTER
CHINA LAKE, CALIFORNIA 93555**

Approved for public release; distribution unlimited.

Naval Weapons Center
AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

FOREWORD

This report was prepared by the Aerosystems Department of the Naval Weapons Center, China Lake, Calif. The report covers investigations conducted on a series of ram air inflated, flexible parachute wings designed to be used in an aircrew emergency escape system. Data were acquired between August 1975 and June 1983 under authority of the Naval Air Systems Command, AIRTASK A3400000/066B/5f41451404, Aircrew Gliding Escape System.

This report was reviewed for technical accuracy by Donald Goodrich.

Approved by
C. V. BRYAN, *Head*
Aerosystems Department
23 September 1983

Under authority of
K. A. DICKERSON
Capt., U.S. Navy
Commander

Released for publication by
B. W. HAYS
Technical Director

NWC Technical Publication 6098

Published by . . . . Aerosystems Department
Collation . . . . Cover, 20 leaves
First printing . . . . 105 copies

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
NWC TP 6098

2. GOVT ACCESSION NO.
AD-A139 928

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
Aircrew Gliding Escape System (AGES) Exploratory Development Investigation of Aircrew Emergency Escape Ram-Air Inflated, Flexible Wing

5. TYPE OF REPORT & PERIOD COVERED
Summary report for August 1975 - June 1983

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Jon T. Matsuo
Manley C. Bulter, Jr.

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Naval Weapons Center
China Lake, CA 93555

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
AIRTASK A3400000/066B/ 5f41451404

11. CONTROLLING OFFICE NAME AND ADDRESS
Naval Weapons Center
China Lake, CA 93555

12. REPORT DATE
September 1983

13. NUMBER OF PAGES
38

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Parachutes
Ejection seat escape system
Aircrew gliding escape system (AGES)
Canopy configurations
Ram-air inflated, flexible wing canopy

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
See back of form.

(UNCLASSIFIED)

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(U) *Aircrew Gliding Escape System (AGES) Exploratory Development Investigation of Aircrew Emergency Escape Ram-Air Inflated, Flexible Wing*, by Jon T. Matsuo and Manley C. Butler, Jr. China Lake, Calif., Naval Weapons Center, September 1983. 38 pages. (NWC TP 6098, publication UNCLASSIFIED.)

(U) The objective of the aircrew gliding escape system (AGES) program is to investigate the feasibility of incorporating a ram-air inflated, flexible wing parachute canopy into contemporary military aircrew ejection seat escape systems. This report describes the research, development, fabrication, and testing of the AGES ram-air inflated parachute wings. The primary focus of the investigation to date was on high-airspeed tests in order to obtain data on the structural integrity of the parachute wing and reefing system design and performance.

(U) Tests were made on 13 configurations over a period of 8 years, including 36 torso dummy drop tests and one cylindrical test vehicle (CTV) test used to evaluate the compatibility of the AGES canopy with the sealed pack developed for the maximum performance ejection seat program (MPES). These tests provided data on the structural integrity of the wing, container design, deployment dynamics, reefing performance, and inflation dynamics. The final configuration was tested at speeds as high as 300 knots indicated airspeed at pack opening without structural damage.

(UNCLASSIFIED)

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

CONTENTS

PROGRAM OBJECTIVE

The objective of the aircrew gliding escape system (AGES) program is to investigate the feasibility of incorporating a ram-air inflated flexible wing parachute canopy into contemporary military aircrew ejection seat escape systems with resulting benefits in these areas:

1. Lower rate of descent (in the "hands-off" mode)
2. Lower opening forces at high speed while reducing the opening times at low speeds
3. Enhanced maneuverability and evasion capabilities

BACKGROUND

Current emergency aircrew escape parachute systems have demonstrated reliable operation but still lack the capability to permit the crewman to maneuver to a favorable landing site. The 28-foot-diameter, flat, circular canopy (28FC) is the most common parachute used in Navy ejection seat aircraft and has recently been fitted with the four-line release modification (which was not available for use in Southeast Asia operations during the Vietnam War). The four-line release system greatly reduces the oscillation of the canopy and provides for a very limited maneuverability. However, significant problems include high rate of descent; high opening shock at high speeds, and slow opening at low speeds, which requires the use of a spreader gun, a drogue gun/deployment rocket, or a combination of both with some systems. The weight of these devices causes the canopy to sink, which in addition to the long suspension lines aggravates the problem of parachute entanglement in water landings.

The only other canopy in current use in Navy ejection seats is the GQ Aeroconical parachute installed in the Martin-Baker seat used in the F-18 aircraft. The Aeroconical is a 5.2-meter, round parachute with mesh-covered vents in the rear of the canopy that give the parachute forward speed. The combination of a high rate of descent and a horizontal velocity component leads to a high total impact velocity. This problem has given rise to a program to replace the Aeroconical with the Automatic Inflation Modulation (AIM) parachute manufactured by Irvin Industries Canada.

GENERAL DESCRIPTION OF RAM-AIR PARACHUTES

Ram-air inflated, gliding parachute wings are commonly constructed as a double-surface airfoil supported by numerous suspension and rigging lines at various points on the canopy. The upper and lower surfaces are joined together with vertical panels, called ribs, that are used to shape the canopy into an airfoil. The canopy itself is constructed from zero-porosity nylon ripstop cloth and nylon reinforcing tapes.

Figure 1 is an overall view of a typical ram-air inflated parachute of this type. The openings at the front of the canopy allow the "ram-air" (from the forward speed in gliding flight) to pressurize the canopy and maintain the airfoil shape. Notice that the suspension lines are arranged in four rows of eight lines each, and the control lines are at the trailing edge of the parachute. The suspension line rows are rigged to differential lengths to set the angle of incidence of the canopy.

Opening Characteristics and Reefing Systems

The opening of ram-air inflated gliding wing parachutes is so rapid that some type of reefing system must be used to prevent structural damage to the parachute and injury to the jumper. Over the past 15 years, many different types of reefing devices were tried and abandoned; however, two basic types of reefing devices proved suitable for intentional sport parachute jumping and are in wide use today.

The first successful system was developed by Para-Flite, Inc., Pennsauken, N.J., and is commonly referred to as the "ropes and rings" method of reefing, although its proper name is Pilot Chute Controlled Reefing (PCR). Several versions of this basic system are in use, one of which is shown in Figure 2.

The PCR system is constructed as a series of rings installed on the periphery of the lower surface of the canopy and at several locations near the center of the lower surface. Cotton buffer pads are sewn on the upper and lower surfaces near the center of the canopy with large grommets installed in both the upper and lower buffers. The reefing line or "rope" is attached to the pilot chute at one end; the other end is then routed down through the grommets in the buffers, out to and around the periphery through all of the rings on the lower surface, then back to the center of the canopy and up through the wing to the pilot chute.

When the canopy is folded during packing, the reefing line is drawn tight by pulling the pilot chute and the excess reefing line (40 to 50 feet) out through the top of the canopy, which constricts the lower surface of the parachute; the excess reefing line is stowed on the outside of the deployment bag. In operation, the drag of the pilot chute on the reefing line resists the spreading force of the canopy, which acts to draw the reefing line back through the grommets as the canopy opens.

The development of the PCR system led to the first commercially successful ram-air parachutes; however, the PCR system proved to be prone to entanglement and fouling unless very carefully packed. This problem eventually led to the introduction of slider reefing.

The slider (or sail slider) is a small rectangular section of canopy cloth, reinforced on the edges with lightweight webbing, with a large grommet or D-ring in each corner. One riser line group from each of the four risers is routed through the grommet in the corresponding corner of the slider. During packing, the slider is pulled up against the lower surface of the canopy; as the parachute opens, the spreading force of the canopy is resisted by the slider, which is held up by the force of the free-stream airflow. The slider is identified in Figure 1.

Flight Controls and Deployment Brakes

Ram-air inflated gliding wing parachutes are controlled by lines attached to the trailing edge; these upper control lines (3 to 6 per side) converge and join a single lower control line per side, which is routed through a guide ring on the back of the rear riser and terminates at a control handle of some sort. In flight these lines are deflected downward by the user to turn or slow the parachute. The control stroke of the parachute is the total distance the control handles must be moved from the full-up position to the point where the canopy enters a steady-state stall or becomes unstable; control deflections are sometimes given as a percentage of the full stroke or as a measurement in inches.

Very rapid turn rates can be achieved by most ram-air wings if the full control authority available is used. By deflecting both sides of the control lines at the same time during landing, a flare maneuver, similar to landing an airplane, can be executed, which results in a very low rate of descent and low forward speed when properly done.

These same control lines are used to set the "deployment brakes," which are used to prevent the canopy from surging forward during the opening process. The deployment brakes are set at about 50% of the total control stroke available for the particular canopy. Generally, the opening forces can be modulated by the deployment brake setting. The forces will increase as the deployment brake setting is increased from 0 to 100% (steady-state stall); however, there are practical limits on the setting for the deployment brakes. If the brakes are set beyond a certain point, which varies from canopy model to model, the parachute will experience a dynamic stall on opening, which will set up a rapid fore and aft oscillation. If the deployment brakes are set above a particular point (also varies with model) the parachute will not open reliably. The most common setting for sport ram-air parachutes is just above the point where the parachute experiences a dynamic stall on opening.

ADVANTAGES OF USING GLIDING PARACHUTES IN AIRCREW ESCAPE SYSTEMS

There has been much discussion recently about the effects of the glide ratio on the landing injury rate for parachutes having the same total impact velocity but differing in the relative magnitudes of the vertical and horizontal components. To date there has been no substantial work in this area although the most popular hypothesis suggests that the lower the rate of descent (vertical component) for a given total impact velocity, the lower the subsequent landing injury rate. These discussions are understandably important to the AGES project in that the canopy under development has a low rate of descent but a high forward speed in the user-selected full-glide mode, which gives a higher total velocity (for an uncontrolled landing in the full-flight mode) at impact, but may or may not lead to a change in the injury rate. The "hands-off" (recovery of an unconscious or disabled ejectee) low-glide opening mode for the AGES parachute has yet to be demonstrated, but is expected to provide a vertical rate of descent of less than 20 fps with a horizontal velocity of less than 8 fps.

The advantage of landing a ram-air parachute in the full-glide mode is realized only when the ejectee is conscious and able to "fly" the parachute. With the proper technique, it is possible to land a ram-air parachute at a total impact velocity of less than 5 fps. This landing technique is accomplished by a flare maneuver that results in a dynamic stall condition at the exact instant of impact. Under conditions other than ideal, the "hands off" performance of any parachute becomes critical with respect to injury avoidance.

OPERATIONAL REQUIREMENT

The essential requirement of any replacement parachute is that the ejectee must be no worse off, under any conditions, than he is with the canopy now in use (28FC). The need for an improved parachute for aircrew automated escape systems arises from the shortcomings of the parachutes that are presently in use. The end result is that the Navy suffers the loss from the fighting forces of a percentage of ejectees (either temporarily or permanently) due to these problems.

Over and above the problems of high opening shock, high rate of descent, slow opening at low speeds, and water entanglement is the lack of any inherent capability of the present parachutes to aid the ejectee in evading enemy ground forces or selecting a more favorable landing site. If aircrewmen during the Vietnam conflict had possessed the capability of gliding away from a hostile, heavily defended area to a site more suitable for rescue or evasion, fewer of them might have been captured.[1]

REQUIREMENTS FOR EMERGENCY ESCAPE SYSTEM GLIDING PARACHUTES

The general requirements for an emergency escape system gliding parachute are as follows:

1. The aircrewman must have the option of selecting a full-glide capability with a glide ratio (defined as ratio of horizontal velocity to vertical velocity) of greater than 3:1 with the appropriate maneuverability; however, the parachute should provide a low-glide "hands-off" mode after opening to accommodate an injured or unconscious aircrewman.
2. The parachute should have a suitable means of control, such as control lines with handles. The flight control system of the parachute should preclude the possibility of inadvertently stalling the canopy during maneuvering yet provide the ability to modulate the forward speed of the canopy with simultaneous left and right control inputs. The rate of turn with maximum differential control input should be between 45 and 90 deg/s (4 to 8 seconds for a 360-degree turn).
3. The parachute must operate at pack open airspeeds as high as 300 KIAS at 15,000 feet MSL; and at speeds as low as 65 fps for a ground level ejection.
4. The loads on the ejectee must not exceed 4,500 pounds (15 g's for 300 pounds suspended weight) for longer than 0.020 second during any phase of the opening process in any part of the operational envelope. Reefing is permitted only if the zero-zero egress condition is not compromised.
5. A stable descent must be achieved within 100 feet of altitude loss after opening.
6. The desirable maximum landing velocity for the "hands-off" condition at 300 pounds suspended weight is
   a. Total impact velocity of less than or equal to 25 fps
   b. Horizontal velocity of less than or equal to 8 fps
   c. Vertical velocity of less than or equal to 20 fps
      Note: This performance exceeds the current specification in MIL-S-18471G.
7. The parachute assembly should be retrofitable into presently operational Navy emergency escape parachute systems without structural changes to the containers or seat interface, which will require that the weight and volume of the ram-air canopy be equal to or less than that of the 28FC. The service life and repack interval must also equal or better the 28FC.
8. The introduction of a new parachute assembly such as the ram-air inflated gliding parachute should not demand any changes in the equipment required at squadron or Aircraft Intermediate Maintenance Depot (AIMD) and logistical support levels. However, the introduction to the Fleet of any new technology

[1]Office of Naval Research. *Naval Combat Search and Rescue*, by Martin G. Every, BioTechnology, Inc., Falls Church, Va. Washington, D.C., ONR, September 1979. Publication UNCLASSIFIED.

such as the ram-air parachute will require very careful training and monitoring of maintenance personnel during the transitional period. The packing and maintenace of ram-air parachutes is no more difficult than the systems that are presently in use but they demonstrate a fundamentally different technology and must be treated as such.

9. Suitable training methods must be devised to familiarize aircrewmen with the characteristics and capabilities of the parachute without unduly exposing them to risks during the training process itself.

Appendix A contains the CNO Draft Operational Requirement (OR) for HighGlide--Ratio Parachute in Ejection Seat Aircraft. The OR addresses some of the problems with the 28FC canopy and the situations that would require the use of a high-glide canopy. Although this version of the OR was recently cancelled, it is presently being rewritten. It is anticipated that a new OR will cover approximately the same points.

TEST ITEMS

Pilot Chute Controlled Reefing as described above was used on the majority of the parachutes for the first 26 tests; at the end of this series of tests it was evident that a fundamental change in the reefing system would be necessary to make any further progress.

Several variations of a fixed-length reefing line system severed by pyrotechnic cutters were used subsequent to Test 26; all of these systems used slider reefing in addition to the fixed-length reefing line. These systems are fully described in the test description section on each configuration.

Most of the test parachutes were packed in NB-7 back parachute containers modified with the addition of internal staging flaps, which are used to hold the deployment bag in the pack tray until the pilot chute and bridle line have completely deployed (see Figure 3). For one test on Configuration 13, the canopy was packed in a sealed container that was developed for the Maximum Performance Ejection Seat (MPES). This container measures 12 by 12 by 6 inches and requires pressure or vacuum packing for either the 28FC or the AGES parachute. The pack volume of the AGES canopy was approximately 10% smaller than the 28FC when packed under identical conditions. This test was conducted using a Cylindrical Test Vehicle (CTV) rather than a torso dummy.

The deployment sequence begins with static line or actuator opening of the pack; the pilot chute deploys and extracts the deployment bag. At line stretch, as the drag surface is exposed, the cutters are initiated and the reefing system sequences to full open. In most instances, the canopy was deployed with the trailing edge deployment brakes set. During some of the tests, the pilot chute was released with a cutter in order to let the PCR system fully retract; in other tests, cutters were used to release the deployment brakes or to set a turn condition to prevent the canopy from flying off of the range. A typical opening sequence is shown in Figure 4.

SUPPORT EQUIPMENT

The following equipment was used during the torso dummy drop tests:

1. Parachute System.

   a. Container. All parachute wings were packed in a modified NB-7 container (Figure 3), or a modified Mini-System container (very similar

to NB-7) except for one test which used a cylindrical test vehicle (CTV).

b. Deployment Initiator. A static line pack opening system was used for all airdrops from the U-1B, C-8 and C-117 aircraft as well as the last two drops from the A-3. Model 1000 HiTek parachute actuators with a 0.75 second time delay were used on the remaining A-3 aircraft drop tests. An aft door release system was used for the F-4 aircraft CTV test.

c. Pilot Parachute. Reinforced 40-inch pilot parachutes from the A-7 aircraft braking parachute assembly and other similar types were used for all tests.

d. Pyrotechnic cutters. Pencil type reefing line cutters of various sizes and time delays were used to release the pilot parachute after full inflation, release deployment brakes after full-braked inflation, release the reefing rope after full inflation, and provide the time sequencing for the reefing system on the last ten tests.

2. Test Loads. Torso dummies ranging in weight from 171 to 400 pounds, including canopy and instrumentation, were used except for the one test which used a CTV. The CTV test was to verify that the AGES canopy was compatible with the sealed pack developed for MPES.

3. Drop Test Aircraft. Tests were conducted from the U-1B, C-8, C-117, A-3, and F-4 aircraft.

4. Launch Devices. A rack dividing the bomb bay into four compartments (coffins) was used for gravity drop tests from the A-3. No special equipment was required on the other aircraft.

5. Photographic Equipment. A minimum of three Askania Cinetheodolite cameras were used to obtain space positioning data on all but the last five tests. Frame rate was 5 fps during the opening sequence. Either 16-mm or 35-mm cameras were used to record event times; 16-mm cameras were used for ground-to-air and air-to-air coverage; a variety of still cameras were used for various phases of the documentation.

6. Telemetry Equipment. 7500-pound capacity strain-gage links were installed on the parachute risers; and three-axis acclerometers were installed in the chest cavity of each dummy. The accelerometer data were used as a cross-check on the strain-gage data.

DROP TEST PROCEDURE

Thirty-seven drop tests using torso dummies and a CTV were made under a variety of conditions; in all, thirteen different canopy configurations have been tested.

The torso dummies were pushed out of the side door of the U-1B and the C-117, and off of the tailgate of the C-8 Buffalo; the packs were opened using a conventional break-cord type static line.

In the A-3 aircraft, the dummies were gravity launched from a compartmented rack in the bomb bay. The automatic actuator was armed by a short static line hooked to the aircraft structure and opened the pack 0.75-second after arming.

For the CTV test using the F-4 aircraft, the CTV was dropped from the centerline bomb rack; the aft door of the CTV was ejected after a 1-second delay which released the pilot parachute and started the deployment from the sealed container.

TEST CONDITIONS AND RESULTS

The following sections describe the parachute used in each configuration and a brief discussion of the tests conducted with each configuration and the results. Table 1 lists the physical parameters for each configuration; Table 2 lists the test conditions and data extracted for each test conducted. The airspeeds listed are in knots true airspeed at pack opening unless otherwise indicated.

Packing procedures were identical with those used for standard sport parachute wings, except for the last 11 tests, which used a fixed-length reefing line (with pyrotechnic cutters) and a slider.

CONFIGURATION 1

Description. Commercially available heavy-duty Strato-Cloud canopy with deployment bag and ropes and rings reefing system; seven-cell canopy with approximately 240-square-foot surface area.

Test Purpose. To obtain data regarding the effects on opening dynamics in regard to changes in gross weight; and data on high airspeed deployment dynamics.

Test Conditions:

Test No.	Weight, lb	Airspeed, KTAS
0670	250	230
0674	300	230
0676	350	230
0678	400	230
0680	250	260

Test Results. Test numbers 0670, 0674, 0676 and 0678 performed satisfactorily without damage. The high reefed force of 4,585 pounds and opening force of 5,190 pounds that were recorded during test 0676 were attributed to the blanketing of the pilot parachute by the deployment bag. Test No. 0680 functioned as intended at the higher launch airspeed.

Test Conclusions. The varying of the gross weights from 250 to 400 pounds at the same launch speed does not noticeably affect the deployment dynamics of the parachute wing; conversely, it was evident that increasing the airspeed does change the deployment dynamics.

CONFIGURATION 2

Description. Commercially available heavy-duty Strato-Cloud parachute with deployment bag and ropes and rings reefing system; seven-cell canopy with approximately 240 square-foot surface area.

Test Purpose. To obtain data regarding the effects on opening dynamics in regard to changes in airspeed with no changes in gross weight.

Test Conditions:

Test No.	Weight, lb	Airspeed, KTAS
0671	250	230
0675	250	260
0677	250	290
0679	250	320

Individual Test Results. Tests 0671 and 0679 resulted in major damage; tests 0675 and 0677 were not damaged.

Test Conclusions. The launch airspeeds were varied in 30-knot increments with a constant suspended weight of 250 pounds. As expected, the test results revealed that the deployment dynamics become unpredictable and unreliable at pack-open airspeeds above 250 KTAS. The cell openings received major damage from the high dynamic pressure before and during the reefing sequencing. The drag of the pilot parachute, not measured separately, is believed to add significantly to the total snatch and reefed forces. Blanketing of the pilot parachute by the deployment bag will reduce the effectiveness of the PCR system and increase the opening force.

CONFIGURATION 3

Description. A standard sport Strato-Cloud parachute was modified from a seven- to a five-large-cell parachute wing by removing two complete cells and the half-cell ribs from the remaining cells. A deployment bag was used and the slider was held in place at the stabilizer stop rings and released by 4-second pyrotechnic cutters. The parachute had a surface area of approximately 150 square feet.
Test Purpose. To obtain deployment and reefing data on a parachute constructed without half ribs.

Test Conditions:	Test No.	Weight, lb	Airspeed, KTAS
	0672	250	230

Test Results. Major damage was sustained during the reefed portion of the opening sequence; the parachute remained partially inflated until impact.
Test Conclusion. It is believed that the damage was caused by the use of single large cells rather than the standard cells with a center divider rib.

CONFIGURATION 4

Description. A square planform parachute (aspect ratio=1.0) was used with a deployment bag; the slider was held in place at the stabilizer stop rings and released by two 1.2-second cutters.
Test Purpose. To obtain deployment and reefing data on a square planform parachute.

Test Conditions:	Test No.	Weight, lb	Airspeed, KTAS
	0673	250	230

Individual Test Results. Major damage was sustained during reefing and filling on Test 0673.
Test Conclusions. It is believed that the damage was caused primarily by the reefing system used and was not related to the lower aspect ratio when compared to the other configurations.

CONFIGURATION 5

Description. Commercially available Strato-Star canopy, with deployment bag and ropes and rings reefing system. Planform area of the Strato-Star is approximately 195 square feet.
Test Purpose. To obtain further data on the deployment characteristics of rope and rings reefing system.

Test Conditions:	Test No.	Weight, lb	Airspeed, KTAS
	0681	250	230

Individual Test Results. Test No. 0681 functioned as intended with no damage.
Test Conclusions. Test No. 0681 demonstrated that pack opening airspeeds of 200 KTAS are within the capabilities of this standard sport parachute using the rope and rings reefing system.

CONFIGURATION 6

Description. A heavy-duty five-cell parachute wing with rope and rings reefing system but no deployment bag. The deployment brakes were released using 4-second delay cutters. The planform area of this canopy was approximately 146 square feet.
Test Purpose. To obtain data on the deployment characteristics, reefing performance, rate of descent, and full-glide capabilities of a small five-cell canopy.
Test Conditions:

Test No.	Weight, lb	Airspeed, KTAS
0266	300	69
0271	171	114

Individual Test Results. On Test No. 0266 the pilot chute was not fully retracted by the rope and rings reefing system, and the left end cell remained partially closed. The deployment brakes were released by cutters as designed. On Test No. 0271, the reefing and brake release functioned as planned.
Test Conclusions. The rate of descent requirements as stated in the Operational Requirements may possibly be obtained with a five-cell parachute wing.

CONFIGURATION 7

Description. Two major advancements in the state-of-the-art sport parachute canopy cloth and fabrication techniques were used in the construction of this canopy. The standard 1.5-oz/yd nylon ripstop was replaced by a 1.25-oz/yd nylon ripstop cloth. This parachute wing was identical to the lightweight military Strato Cloud canopies that were being evaluated for high-altitude offset insertion parachute operations at the Army's Special Forces School. Rope and rings reefing without a deployment bag was used. The planform area of this parachute is approximately 240 square feet.

Test Purpose. To evaluate the new material and fabrication techniques and obtain further data on the rope and rings reefing system.
Test Conditions:

Test No.	Weight, lb	Airspeed, KTAS
0267	300	101
0268	300	102
0269	300	--
0270	300	229
0272	300	320
0273	300	345

Individual Test Results. On Test No. 0267, low-speed deployment, reefing, and braked full-open data were obtained. On Test No. 0268 and 0270, the effects of increased pack open airspeed and full-glide performance data were obtained. On Test No. 0269 the reserve parachute deployed immediately after launch, precluding the collection of any useful data. Similarly, data from Test No. 0272 were not available because the pilot parachute released at the moment of pilot parachute/reefing line stretch, and the wing ruptured. On Test No. 0273, high-speed film coverage revealed that major damage

occurred at line stretch and during the partially reefed opening. The damage was so extensive that no specific, logical engineering redesign or modification information could be obtained; the canopy did not remain inflated.
Test Conclusions. It was concluded that the new materials and fabrication techniques did not adversely affect the deployment, reefing and braked full-open performance within the operational envelope of the rope and rings reefing system.

CONFIGURATION 8

Description. This was the first heavy-duty design of the military StratoCloud parachute using the 1.25-oz/yd nylon ripstop cloth. The rope and rings reefing system was used without a deployment bag. The planform area of this parachute is approximately 240 square feet.
Test Purpose. To obtain data on structural integrity, deployment characteristics and reefing dynamics.

Test Conditions:	Test No.	Weight, lb	Airspeed, KTAS
	0274	300	353

Individual Test Results. During Test No. 0274 major damage was sustained at line stretch, and the wing streamered until the reserve parachute deployed at approximately 1,000 feet AGL. High-speed film coverage and post-test inspection of the assembly did not reveal a specific cause of the failure relating to the unique features of this configuration. It is believed that the two center suspension lines (400 pound tensile strength) and the associated reefing ring attachments failed first.
Test Conclusions. Suspension line breaking strength was inadequate and was increased to 600 pounds for subsequent tests.

CONFIGURATION 9

Description. The suspension lines of the heavy-duty military Strato-Cloud parachute tested as configuration number 8 were changed from 400 to 600 pounds breaking strength. Rope and rings reefing without a deployment bag was used.
Test Purpose. To obtain structural, reefing, and deployment data.

Test Conditions:	Test No.	Weight, lb	Airspeed, KTAS
	0275	300	372
	0699	300	308

Individual Test Results. Test No. 0275 was inadvertently conducted at airspeeds faster than planned. Although the parachute wing sustained major damage during reefed opening and canopy development, it remained inflated. On Test No. 0699, the pilot parachute released prematurely at line stretch, the parachute wing ruptured, and no test data were obtained.
Test Conclusions. The rope and rings reefing system becomes unpredictable during high airspeed deployments.

CONFIGURATION 10

Description. Two cells were removed from the heavy-duty military Strato-Cloud canopy (configuration No. 8); this canopy used rope and rings reefing without a deployment bag. The planform area of this parachute was approximately 175 square feet.

Test Purpose. The two cells were removed to determine if this method could be used to reduce weight and bulk and still remain within the desired performance parameters.

Test Conditions:

Test No.	Weight, lb	Airspeed, KTAS
0002	300	100
0067	300	91

Individual Test Results. On Test No. 0002, the wing was deployed with an excessive deployment brake setting, and the parachute descended in the stalled condition. On Test No. 0067 the wing deployed successfully.

Test Conclusions. There seem to be no new apparent deployment reefing or braked full-open problems related to a five-cell canopy as compared to a seven-cell canopy.

CONFIGURATION 11

Description. A heavy-duty five-cell parachute was fabricated that included all of the previously developed changes affecting the structural integrity and performance. Rope and rings reefing system was used without a deployment bag. The planform area of this parachute was approximately 175 square feet.

Test Purpose. To determine whether a five-cell parachute wing could be used to reduce the weight and bulk but keep the performance within the desired limits.

Test Conditions:

Test No.	Weight, lb	Airspeed, KTAS
001	300	353

Individual Test Results. On Test No. 001 the parachute wing began to rupture shortly after line stretch; then streamered until impact. Post-test inspection revealed that one front suspension line and both lower control lines had failed.

Test Conclusions. The rope and rings reefing system performance, which was predictable and reliable to approximately 200 KTAS launch speeds, is inadequate above this speed. A different reefing system must be developed for use at speeds above 200 KTAS.

CONFIGURATION 12

Description. A heavy-duty seven-cell parachute was fabricated, which included all of the previously developed changes affecting the structural integrity of the parachute; an important change was an increase in the strength of the reinforcing tapes used on the leading edge. A two-stage reefing system was used; the first-stage reefing line was 3.25 feet long and passed through the rings on the lower surface periphery of the canopy and the rings on the top leading edge of each of the half-cells. The second-stage reefing line was 6 feet long and passed through the four grommets in the corners of the slider and through the four slider stop rings on the lower edge of the stabilizer panels. Both reefing line cutters were armed at line stretch (deployment bag opening); the first-stage delay was 2.0 seconds, and the second-stage delay was 4.0 seconds. The planform area of this canopy was approximately 260 square feet.

Test Purpose. To test the two-stage reefing system for high airspeed deployments.

Test Conditions:

Test No.	Weight, lb	Airspeed, KTAS
0610A	300	341
0610B	300	338

Individual Test Results. On Test No. 0610A the canopy was dumped from the deployment bag before line stretch; this precluded an orderly, lines-first deployment sequence. High-speed film coverage revealed that only one reefed stage was evident.

The parachute wing received major damage but approximately 80% of the canopy remained inflated. Post-test inspection revealed that the reefing system had malfunctioned. On Test No. 0610B the parachute functioned as designed; however, the telemetry system malfunctioned and no telemetry data were obtained.

Test Conclusions. The structure of the deployment bag must be strengthened in order to ensure that the canopy stays in the deployment bag during the deployment sequence. The fixed-length reefing system shows promise but this particular method is prone to entanglement with the slider; a different method was devised for the next configuration. Although, the canopy in Test No. 0610A suffered extensive damage during deployment, it remained inflated and had a stable descent with a slight turn; this was probably a survivable malfunction.

CONFIGURATION 13

Description. A new design, heavy-duty seven-cell parachute wing using a Lissaman 7808 airfoil, spanwise construction for the top and bottom surfaces, full deployment bag, and two-stage reefing, was constructed by Para-Flite, Inc. Two slightly different configurations of this reefing system, both of which make use of rings installed around the lower periphery of the canopy and on the upper leading edge of each half-cell at the intersection of the nonloaded rib, were used successfully on configuration 13. A ring is also installed on the center of the slider and is used to hold the slider in place until the reefing line is severed. Redundant cutters are used at all locations.

The two-stage reefing system works as follows: The first-stage reefing line is passed through the reefing rings on the lower leading edge of each main cell at the suspension line attachment point and through the rings on the upper leading edge of each half cell. The line is alternately routed through the upper and lower rings, then drawn down to approximately 8 inches. The first stage serves to keep the cell openings closed during the initial exposure of the drag surface; time delays of 1.0 and 0.7 seconds have been used successfully for the first stage.

The second-stage reefing line is passed through the rings on the lower leading edge, then around the lower periphery of the canopy; the slider is held up against the lower surface of the canopy by the second-stage reefing line, which passes through the ring installed on the center of the slider. The length of the second-stage reefing line is 3.25 feet. Second-stage time delays of 2.0 and 1.4 seconds have been used successfully; both the first- and second-stage cutters are activated at line stretch as the canopy emerges from the deployment bag.

The single-stage reefing system is similar to the second-stage of the system above; the difference is that the rings on the upper leading edge of the half-cells are also threaded onto the reefing line for the single-stage system. This system keeps the nose openings closed until full disreef, whereas the two-stage system releases the nose openings when the first stage disreefs.

For most of these tests the canopies were packed in a modified NB-7 or modified Mini-System container; however, on Test No. 1405, the parachute was packed in a sealed container after pressure packing. The packed volume was approximately 10% less than that of the 28FC when packed under the same conditions of pressure and vacuum.

Test Purpose. To test an improved two-stage reefing system for high airspeed deployments; to test shorter total reefing times for the two-stage system; to test a

single-stage reefing system with varying total reefing times; and to demonstrate compatibility with the sealed pack system developed for the MPES project.

Test Conditions:

Test No.	Weight, lb.	Airspeed KIAS/KTAS	Altitude Feet, MSL	Reefing Delay 1st/2nd, s
1405	300	255/267	7,500	1.0/2.0
2415-1	300	250/280	8,000	1.0/2.0
2415-2	300	275/306	8,000	1.0/2.0
3400-1	300	305/339	7,500	1.0/2.0
3400-2	300	200/220	7,500	2.0
3400-3	300	250/280	7,500	0.7/1.4
3400-4	300	320/378	15,000	1.0/2.0
3400-5	300	250/278	7,500	2.0
3400-6	300	300/335	7,500	.7/1.4
3400-7	300	85/89	5,000	0.0

Individual Test Results. Test No. 1405, using the sealed pack container and a CTV, functioned as intended; no damage. Test No. 2415-1 functioned as designed; minor damage, an 18-inch tear along a rib seam in the upper surface, did not affect the performance of the wing. Test No. 2415-2 functioned as designed; no damage. All of the tests in the 3400 series were successful and demonstrated pack opening speeds as high as 300 KIAS at altitudes as high as 15,000 feet with no significant structural damage. There was minor damage near a D-line attachment tape on Test No. 3400-4; the line did not separate from the canopy.

After Test No. 3400-2 all riser force data were processed through the VAX 11/780 and plotted on a Versatek plotter for presentation of the data. All of the original oscillograph strip charts were used to cross check the data from these tests. Several samples of these plots are included in Appendix B. Space positioning data were deleted from the last five tests in the 3400 series due to funding constraints.

Test Conclusions. This configuration of the parachute wing met the following performance goals: (a) high airspeed/high altitude deployment demonstrated to 300 KIAS at 15,000 feet MSL; (b) acceptable loads on parachutist during opening (less than 13 g's worst case on AGES-13); (c) lower vertical descent rate; (d) smaller packed volume than the 28FC.

SUMMARY OF RESULTS

The thirty-seven tests conducted in the AGES project demonstrate the problems in applying low-speed sport parachute equipment to the ejection seat environment. It was only with configurations 12 and 13 that the design of the AGES canopies differed significantly from their sport parachute origins. An examination of the individual test results shows that little substantial progress was made until the canopies were designed specifically for this high-speed application.

Configuration 12 is significant in that it is the first of the canopies to use a fixed-length reefing system to control the growth rate of the drag area and also the first of the canopies to control the cell inflation by temporarily closing the cell openings with the reefing line through the tops of the half-cells. AGES-12 also used the "free-bag" method of deployment, which allows the deployment bag to come completely

off the opening parachute, thus reducing the snatch force due to pilot parachute loading and reducing chances of entanglement.

Configuration 13 is the most successful of the canopies used in the AGES project; there have been no structural failures and no malfunctions of the parachute. AGES-13 uses a specialized, spanwise construction technique to form the top and bottom surfaces. This technique allows the use of continuous reinforcing tapes across the full width of the parachute at the leading edge and at all line attachment points. The spanwise construction results in a much stronger parachute with no increase in bulk over conventional construction methods. AGES-13 also controls the drag area growth with fixed-length reefing lines using the system described under Test Conditions and Results.

CONCLUSIONS

1. Based on the exploratory development phase of this project, it has been demonstrated that it is feasible to incorporate a ram-air inflated, gliding parachute wing into a contemporary ejection seat aircraft escape system.
2. The AGES parachute (configuration 13) has met these performance goals:
   a. Structural integrity has been demonstrated at speeds up to 300 KIAS (378 KTAS) at altitudes up to 15,000 feet MSL.
   b. Opening forces on the parachutist of less than 13 g's have been demonstrated for the most severe case to date.
   c. Vertical rate-of-descent of 16 fps has been demonstrated at 300 pounds suspended weight (corrected to sea level conditions).
   d. Pack volume of 10% less than the 28FC when packed under the same conditions.

RECOMMENDATIONS

Two major areas should be investigated during FY 1984. Full-scale engineering development could begin in FY 1985 if these goals can be met in FY 1984.

1. Development and demonstration of a reefing system that is effective at 300 KIAS without compromising the zero-zero ejection condition.
2. Development and demonstration of the capability to deploy the parachute in a minimum glide condition with a glide ratio of less than 0.5:1 in the "hands-off" condition, with the user-selectable option of a high-glide mode, capable of a glide ratio of 3:1 or higher.

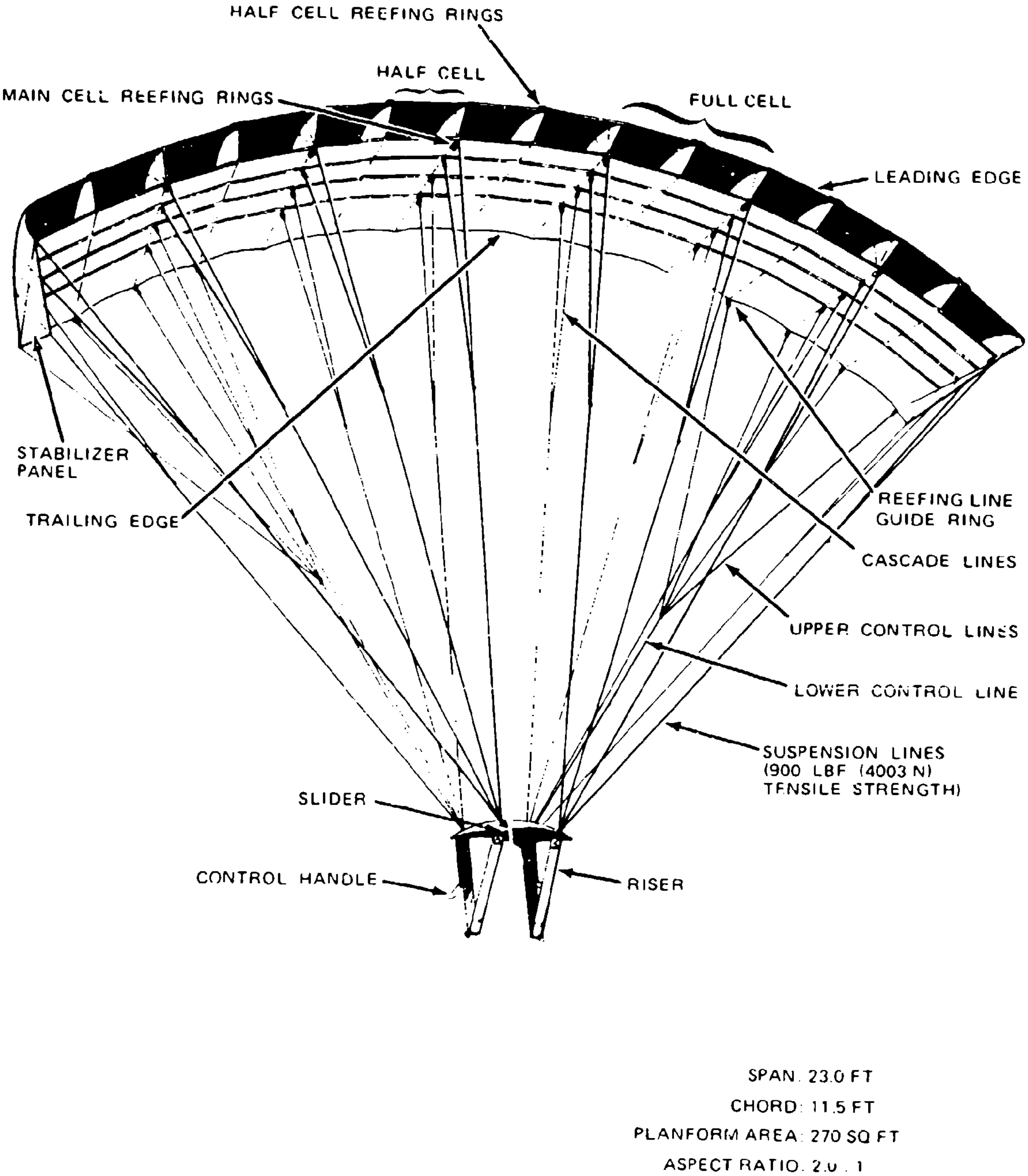


FIGURE 1. Overall View of Ram-Air Inflated Gliding Parachute Wing.

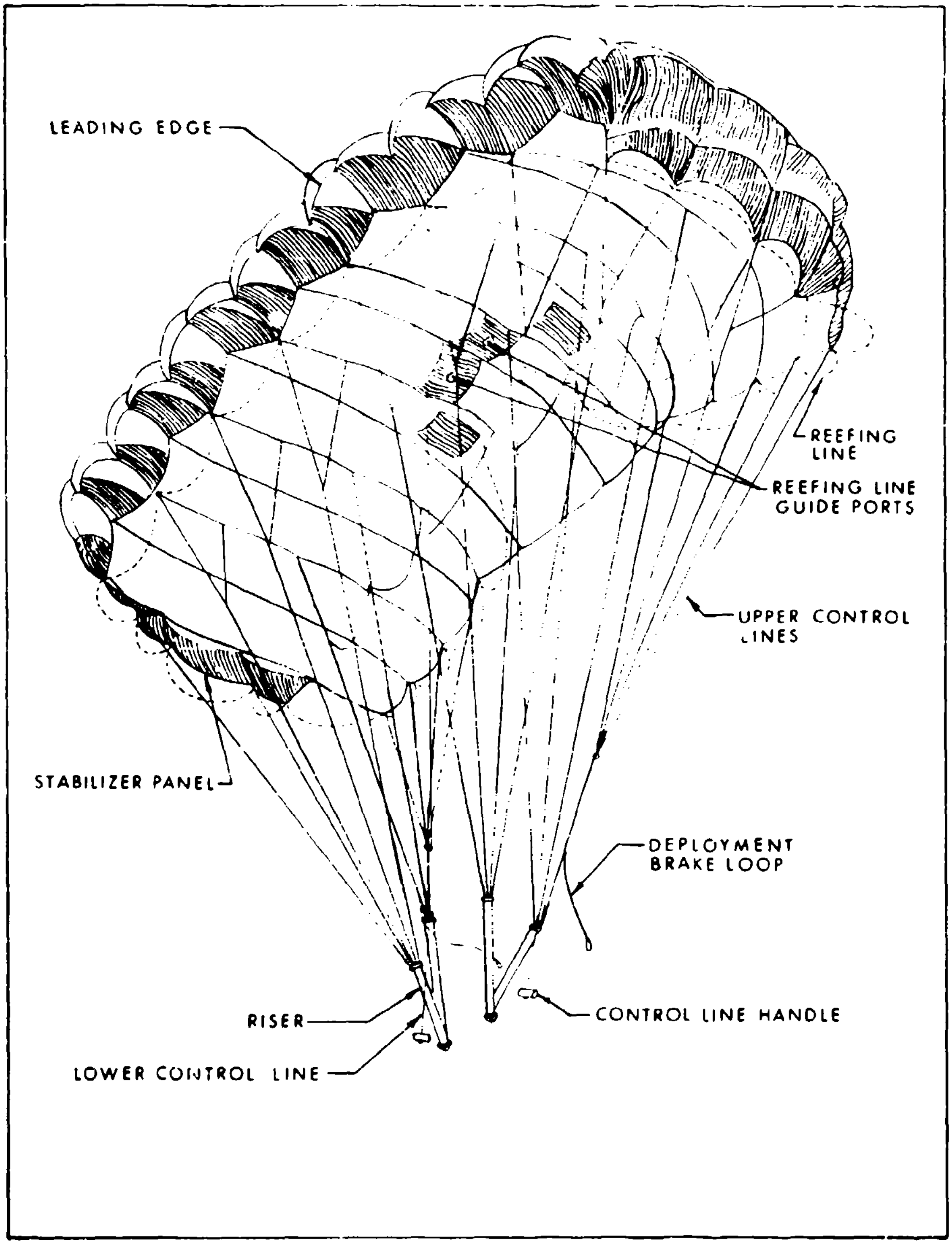


FIGURE 2. "Strato-Cloud" Canopy with PCR Reefing.

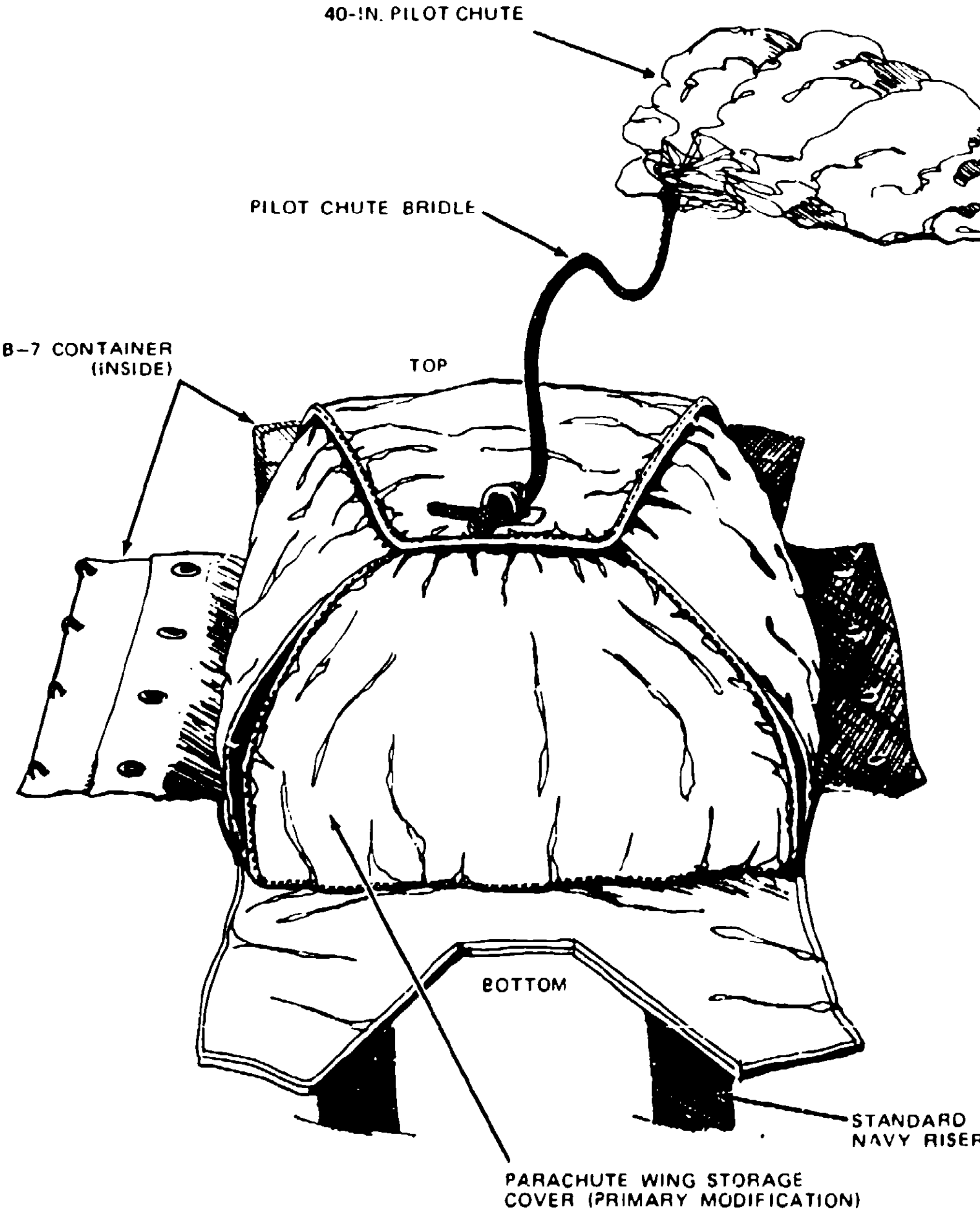


FIGURE 3. Drop Test Container with Internal Staging Flaps.

FIGURE 4. Opening Sequence for Ram-Air Parachute With Fixed Length Reefing Line, Pyrotechnic Cutters, and Slider-Type Reefing. Typical of Configuration 13.

TABLE 1. Test Parachute Physical Descriptic

Item	Test configuratic						
	1	2	3	4	5	6	7
Wingspan, ft (approx.)	20.0	20.0	15.0	10.0	15.0	13.3	20.5
Wing chord, ft (approx.)	12.0	12.0	12.0	10.0	13.0	11.0	12.2
Wing area, ft^2 (approx.)	240.0	240.0	...	100.0	195.0	146.5	243.0
Drag surface material	1.5 oz/yd^2 ripstop nylon	Same	Same	Same	Same	1.5 oz/yd^2 ripstop nylon	1.25 oz/yd· ripstop nylo·
Permeability	0 to 3 cfm, 0.5 in. water	Same	Same	Same	Same	Same	Same
Suspension line breaking strength, lbf	1,200.0	900.0	900.0	1,200.0	750.0	400.0	400.0
Reinforcement tapes (other than suspension line V-tapes)	Upper, lower and spanwise seams	Every other upper and lower seam	None	Upper, lower and spanwise seams	None	Yes	Yes, 1.75-i wide
Number of cells							
Large	7.0	7.0	5.0	4.0	5.0	4.0	7.0
Small	14.0	14.0	...	8.0	10.0	10.0	14.0
Reefing rope length, ft	68.0	68.0	...	...	64.0	64.0	78.0
Suspension line, length (base)							
Leading edge, in.	13.8	13.8	12.0	13.8	17.3	9.7	11.6
Trailing edge, in.	15.6	15.6	...	15.6	...	11.9	13.8
Number of spanwise suspension lines	8.0	8.0	6.0	5.0	6.0	6.0	8.0
Number of chordwise suspension lines	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Number of spanwise brake lines	8.0	8.0	6.0	4.0	6.0	3.0	4.0

*See applicable Test Condition for reefing information.

ute Physical Description.

Test configuration							
6	7	8	9	10	11	12	13
13.3	20.5	20.5	20.5	14.4	14.4	21.25	23.0
11.0	12.2	12.2	12.2	12.2	12.2	12.2	11.5
46.5	243.0	243.0	243.0	175.5	175.5	260.4	270.0
oz/yd^2 nylon	1.25 oz/yd^2 ripstop nylon	1.25 oz/yd^2 ripstop nylon	1.25 oz/yd^2 ripstop nylon	1.25 oz/yd^2 ripstop nylon	1.5 oz/yd^2 ripstop nylon	1.1 oz/yd^2 ripstop nylon	1.1 oz/yd^2 ripstop nylon
me	Same	Same	Same	Same	Same	Same	Same
0.0	400.0	400.0	900.0	400.0	900.0	400.0	900.0
es	Yes, 1.75-in. wide	Yes, 0.75-in. wide	Yes, 0.75-in. wide	Yes, 0.75-in. wide	Yes, 0.75-in. wide	Yes, 0.75-in. wide	Yes, 1.0-in.
4.0 0.0	7.0 14.0	7.0 14.0	7.0 14.0	5.0 10.0	5.0 10.0	7.0 14.0	7.0 14.0
4.0	78.0	78.0	...	64.0	64.0	*	*
.7 .9	11.6 13.8	11.6 13.8	11.6 13.8	11.6 13.8	11.6 13.8	11.5 12.5	11.3 12.3
.0	8.0	8.0	8.0	6.0	6.0	8.0	8.0
.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
.0	4.0	4.0	4.0	4.0	4.0	8.0	8.0

2

TA

Date	Test configuration no.	Test no	Gross weight, lbs	Launch airspeed		Pack open airspeed, ft/s	Altitude at pack open, ft	Line stretch reefed airspeed, ft/s	Altitude lost from pack open to line stretch, ft	Lin fo
				KTAS	ft/s					
11 May 76	1	0670	250	230	422	385	3,174	305	42	
11 May 76	2	0671	250	230	423	385	3,143	330	35	
12 May 76	3	0672	250	230	416	372	3,142	334	24	
12 May 76	4	0673	250	230	N/A					
13 May 76	1	0674	300	230	408	376	3,214	337	35	
13 May 76	2	0675	250	260	451	401	3,243	357	20	
14 May 76	1	0676	350	230	449	412	3,030	380	24	
14 May 76	2	0677	250	290	549	471	3,122	422	18	
18 May 76	1	0678	400	230	420	395	3,007	361	31	
18 May 76	2	0679	250	320	571	501	3,109	445	17	
20 May 76	1	0680	250	260	456	401	3,088	361	15	
20 May 76	5	0681	250	230	306	354	3,032	314	25	
6 Jan 78	6	0266	300	69	117	116	3,844	125	88	
25 Jan 78	7	0267	300	101	171	170	3,676	166	36	
27 Jan 78	7	0268	300	102	173	177	4,035	174	39	
3 Feb 78	7	0269	300	...	...	...	...	...	...	

Gliding Escape System Test Data for Test Configurations 1 Through 13.

Deployment time, s	Reefed (open) force, lbf	Reefed duration, s	Altitude lost during reefing, ft	Disreef airspeed, ft/s	Opening force, lbf	Development time, s	Altitude lost during development, ft	Pack open to canopy full open, s	Altitude lost from pack open to full open, ft
0.76	1,750	1.06	66	131	2,240	0.23	12	2.05	120
0.64	4,420	0.40	23	257	4,130	0.71	43	1.76	101
0.45	1,700	1.0	N/A	N/A	4,410	N/A	N/A	N/A	N/A
0.73	1,920	0.93	50	171	3,140	0.99	46	2.65	131
0.39	. . .	0.92	52	231	. . .	0.416	21	1.72	93
0.50	4,575	0.51	28	298	5,190	0.61	32	1.62	88
0.39	4,250	1.04	51	200	2,500	1.47	46	2.90	114
0.54	2,400	1.20	82	212	3,850	0.62	24	1.84	88
0.38	2,950	0.62	30	290	3,990	0.57	25	1.56	72
0.36	2,600	0.86	49	180	3,400	0.62	24	1.84	38
0.547	1,420	1.25	65	143	1,400	0.90	41	2.69	131
1.65	350	0.71	56	105	1,082	0.57	36	2.93	180
0.96	300	1.73	118	119	1,300	1.53	80	4.23	234
1.03	400	2.71	187	75	876	5.84	85	9.58	311
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

2

Date	Altitude lost from pack open to full open, ft	Terminal rate of descent, ft/s	Remarks
11 May	120	...	Good test.
11 May	101	...	Good test. Deployment bag blanketed the pilot chute. Major damage to center cells.
12 May	N/A	...	Major damage during reefing, 4-s reefing and diaper.
12 May	→	...	Major damage during reefing and filling, 1.2-second reefing.
13 May	131	...	Good test.
13 May	93	...	Good test. Lost one riser force.
14 May	88	...	Good test. Deployment bag went into pilot chute.
14 May	114	...	Good test. Main chute exposed before links were played out.
18 May	88	...	Good test.
18 May	72	...	Good test. Main damaged but remained inflated. Two front lines and four brake lines broken.
20 May	38	...	Good test (5th drop).
20 May	131	...	Good test (1st drop).
6 Jan 7!	180	29	Brakes release 4 seconds after line stretch. Pilot chute left on. Left-end cell tucked.
25 Jan '	234	15	Good test.
27 Jan '	311	17	Full glide.
3 Feb 7	...	...	Reserve chute deployed immediately after launch; data not reduced. Test parachute deployed later and remained fully inflated.

3

Date	Test configuration no.	Test no.	Gross weight, lbs	Launch airspeed		Pack open airspeed, ft/s	Altitude at pack open, ft	Line stretch reefed airspeed, ft/s	Altitude l from pac open tc line stretc ft
				KTAS	ft/s				
8 Feb 78	7	0270	300	229	386	363	4,035	331	75
17 Feb 78	6	0271	171	114	192	170	3,743	155	15
15 Mar 78	7	0272	300	320	540 -	...	...	...	...
21 Jun 78	7	0273	300	345	583	575	4,159	512	...
27 Jun 78	8	0274	300	353	597	517	3,973	465	...
20 Jul 78	9	0275	300	372	629	544	4,097	483	...
21 Aug 78	9	699	300	308	521	464	4,126	451	...
19 Oct 78	10	002	300	...	146	145	4,150	...	...
27 Oct 78	10	0067	300	91	154	146	4,090	143	33
31 Oct 78	11	001	300	353	597	515	4,201	446	...
13 Nov 80	12	0610A	300	341	576	572	6,414	532	...
13 Nov 80	12	0610B	300	338	571	566	6,427	499	13
26 Aug 81	13	1405	300	267	452	452	7,632	439	19
22 Sep 82	13	2415-1	300	290	489	430	7,717	414	13
22 Sep 82	13	2415-2	300	306	516	463	7,892	438	10
20 Dec 82	13	3400-1	300	339	573	494	7,630	472	8

C	ltitude lost from pack open to full open, ft	Terminal rate of descent, ft/s	Remarks
8 F	419	16	Full glide.
17 F	198	18	Full glide.
15 M	...	...	Pilot parachute released at pilot chute stretch (no main out); wing ruptured. Data not reduced.
21 J	...	...	Major damage occurred at line stretch and during reefing. Lost riser telemetry. Peak 24 *g* at 0.53 second after pack open. Parachute wing streamed.
27 J	...	...	Major damage occurred at line stretch. Lost riser telemetry. Peak 23 *g* at 0.36 second. Parachute wing streamed.
20 J	...	...	Major damage occurred during reefing and development. Wing remained inflated 0.045 second total duration of line stretch force.
21 A	...	...	Wing ruptured. Data not reduced. Pilot chute released at line stretch.
19 O	...	...	Too much brake; wing in stall configuration. Data not reduced.
27 O	213	20	Good test.
31 O	...	...	Wing ruptured shortly after line stretch. One front main suspension line and both brake lines failed.
13 N	...	...	No force data, TM malfunction. Reefing problems, major damage to wing.
13 N	434	19	No force data, TM malfunction. Two stage reefing functioned as programmed. No damage.
26 A	307	19	Two stage reefing functioned as programmed. No damage.
22 S	294	20	Two stage reefing functioned as programmed. No damage.
22 S	199	17	Two stage reefing functioned as programmed. No damage.
20 D	175	15	Two stage reefing functioned as programmed. No damage.

3

TABLE 2. Gliding Escape System Test Data for Test Configurations 1 Through 13. (Contd.)

...ude lost ...n pack ...en to ...stretch, ft	Line stretch force, lbf	Deployment time, s	Reefed (open) force, lbf	Reefed duration, s	Altitude lost during reefing, ft	Disreef airspeed, ft/s	Opening force, lbf	Development time, s	Altitude lost during development, ft	Pack open to canopy full open, s
75	1,690	0.57	985	1.43	272	173	1,477	0.49	72	2.49
15	...	1.46	...	0.87	136	110	...	0.97	47	3.30
...	...	...	...	...	...	...	...	...	...	...
...	...	0.43	...	...	...	...	...	...	...	...
...	...	0.33	...	...	...	...	...	...	...	...
...	5,081	0.40	2,800	...	...	...	...	...	...	...
...	...	0.38	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...
33	409	0.83	...	0.80	159	86	2,309	0.20	21	3.39
...	7,019	0.53	...	...	...	...	...	...	...	...
...	...	0.34	..	...	...	...	...	...	...	...
13	...	0.45	...	4.54	256	94*	...	3.13*	165	8.12
19	2,321	0.25	2,286	2.03	191	125*	881	1.43*	97	3.87
13	2,165	0.25	1,092	2.17	255	109*	1,456	0.541*	26	2.96
10	2,129	0.24	2,056	2.54	127	94*	1,266	1.1*	62	3.86
8	2,193	0.22	1,946	1.81	97	216*	1,314	1.43*	70	3.46

2

TABLE 2a. AGES Test Data.

Date, 83	Test configuration number	Test number	Gross weight, lb	Launch airspeed			Altitude MSL, ft	Line stretch		Reefed open	
				KIAS	KTAS	Ft/s		Time, s	Force, lbf	Time, s	Force, l
14 Feb	13	3400-2	300	200	225	380	7500	0.492	1981	0.787	568
3 Jun	13	3400-3	300	250	278	470	7500	0.3003	1542	0.857	1609
3 Jun	13	3400-4	300	320	401	680	15000	0.350	1632	0.613	2011
8 Jun	13	3400-5	300	250	278	470	7500	0.250	482	0.7240	1595
8 Jun	13	3400-6	300	300	335	565	7500	0.297	1194	0.616	2181
10 Jun	13	3400-7	300	85	89	150	5000	1.190	2267	N/A	N/A

/

TABLE 2a. AGES Test Data.

Line stretch		Reefed open		Disreef		Maximum force, lbf	Time to full open	Remarks
Time, s	Force, lbf	Time, s	Force, lbf	Time, s	Force, lbf			
0.492	1981	0.767	568	2.901	159	3138	4.342	1-stage reefing; 2.0-s total time
0.3003	1542	0.857	1609	1.6013	1862	3138	2.14	2-stage reefing; 0.7/1.4-s delay
0.350	1533	0.513	2011	1.968	1969	3274	2.686	2-stage reefing; 1.0/2.0-s delay
0.250	482	0.7240	1595	2.083	1926	1926	4.400	1-stage reefing; 2.0-s total time
0.297	1194	0.616	2181	1.716	2510	3701	2.12	2-stage reefing; 0.7/1.4-s delay
1.190	2267	N/A	N/A	N/A	N/A	1928	1.573	Slider reefing only

2

Appendix A

OPERATIONAL REQUIREMENT (OR)

HIGH-GLIDE-RATIO PARACHUTE

FOR

EJECTION SEAT AIRCRAFT

I. OPERATIONAL NEED

a. Threat.

(1) Capture and subsequent incarceration and/or death of combat aircrews subsequent to ejection over hostile territory.

(2) High risk of personal injury due to parachute landing in unfavorable terrain.

b. Operational Problem. Present parachute systems installed in ejection seats of tactical jet aircraft do not provide for maximum evasion capability after ejection over hostile territory. Although aircrew systems change No. 383 (Parachute Four Line Release Modification) does provide limited maneuverability and forward airspeed (3-4 knots) when incorporated into the present, standard navy parachute, its ability to prevent serious injury and enhance evasion must be considered minimal when compared to the potential of parachutes incorporating "present-day" high lift design technology.

II. OPERATIONAL CONCEPT. High-Glide-Ratio parachutes would be used primarily by ejectees to maneuver themselves during parachute descent to avoid unfavorable landing terrain (trees, large rocks, rivers, etc.) and/or avoid the threat of capture by hostile ground forces. Aircrew systems change No. 383 is considered to be an appropriate interim solution, but does not fulfill performance goals as presented in Section III.a. Logistics and training support requirements have not been determined, nor are they considered appropriate for determination at the originator's level. Nevertheless, support in the form of changes to applicable directives concerning parachute systems (e.g., NAVAIR 13-1-6.2 Manual), training of navy survival equipmentmen (PR's) in maintenance of acquired systems and training of potential users is of paramount importance.

III. CAPABILITIES REQUIRED

a. Performance Goals.

(1) OR System Parameters/Criteria.

(a) A "fail safe" and landing mode (including water landing) which will be less hazardous to an aircrewman than the present ejection seat parachute system if the ejectee is unconscious.

(b) Decrease risk of parachute/shroudline entanglement after water landing.

(c) A glide performance ratio of 4:1 or greater.

(d) A sink rate of 16 feet per second or less in the "flight mode".

(e) A sink rate of 28 feet per second or less in the "unglided, or braked mode".

(f) A design which will preclude stall and subsequent loss of safe, controlled flight.

(g) The capability of simple steering and braking in flight to include turning 360 degrees in 10 seconds.

(h) The capability of replacing current inventory parachutes by weight and volume and shape in present parachute containers.

(i) Be compatible with current training, skills, and environments relative to packing, maintenance, and emergency use.

(2) Target Parameters Criteria. The subject system must incorporate listed performance goals without degradation of performance capability throughout the safe operating ranges of present ejection systems.

(3) Operational Employment. This capability will be employed by tactical aircrewmen after ejection over hostile or rugged territory in order to preclude capture by hostile ground forces and/or avoid high injury risk landing areas.

b. Manpower and Personnel Considerations

(1) An increase in manpower requirements is not projected. However, training of maintenance personnel concerning a newly acquired system will be required.

c. Reliability and Maintainability.

(1) Maximum reliability and maintainability with minimal trade-off in operational capability is required for enhancement of aircrew survivability.

IV. QUANTITIES AND COST OBJECTIVES

a. A sufficient quantity of high-glide-ratio parachutes to retrofit all U. S. Navy tactical, ejection seat aircraft (plus sufficient spares) is required. A realistic estimation of total program cost can not be determined at the originator's level.

V. INITIAL OPERATIONAL CAPABILITY (IOC)

a. As soon as feasible.

VI. PROPOSED/ESTIMATED FUNDING

a. To be determined by higher authority.

VII. ON-GOING/RELATED EFFORTS

a. Civilian/Military sport parachuting organizations only, at present.

VIII. PRINCIPLE WARFARE AREA

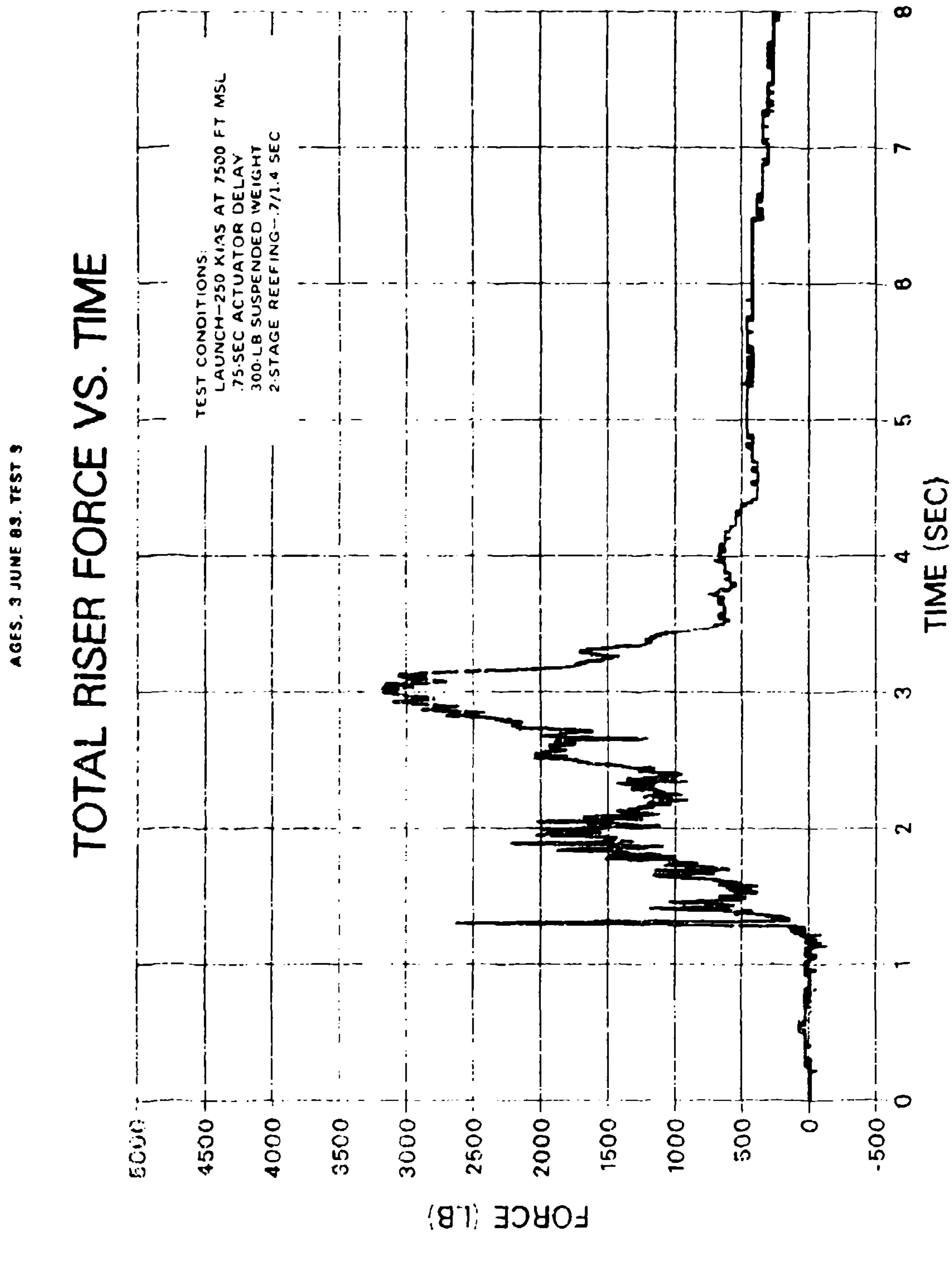
a. To be determined by higher authority.

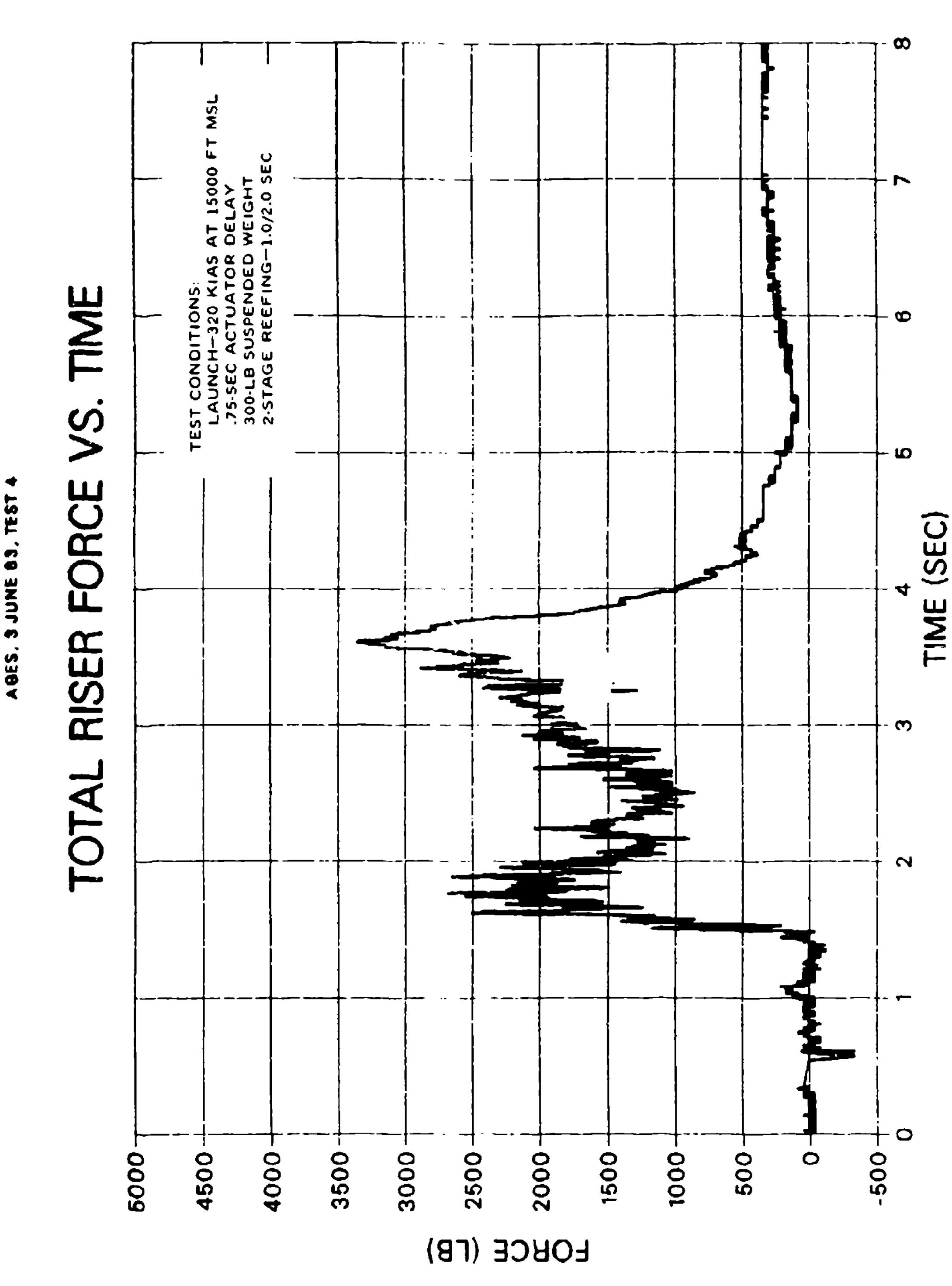
IX. RELATED WARFARE AREA

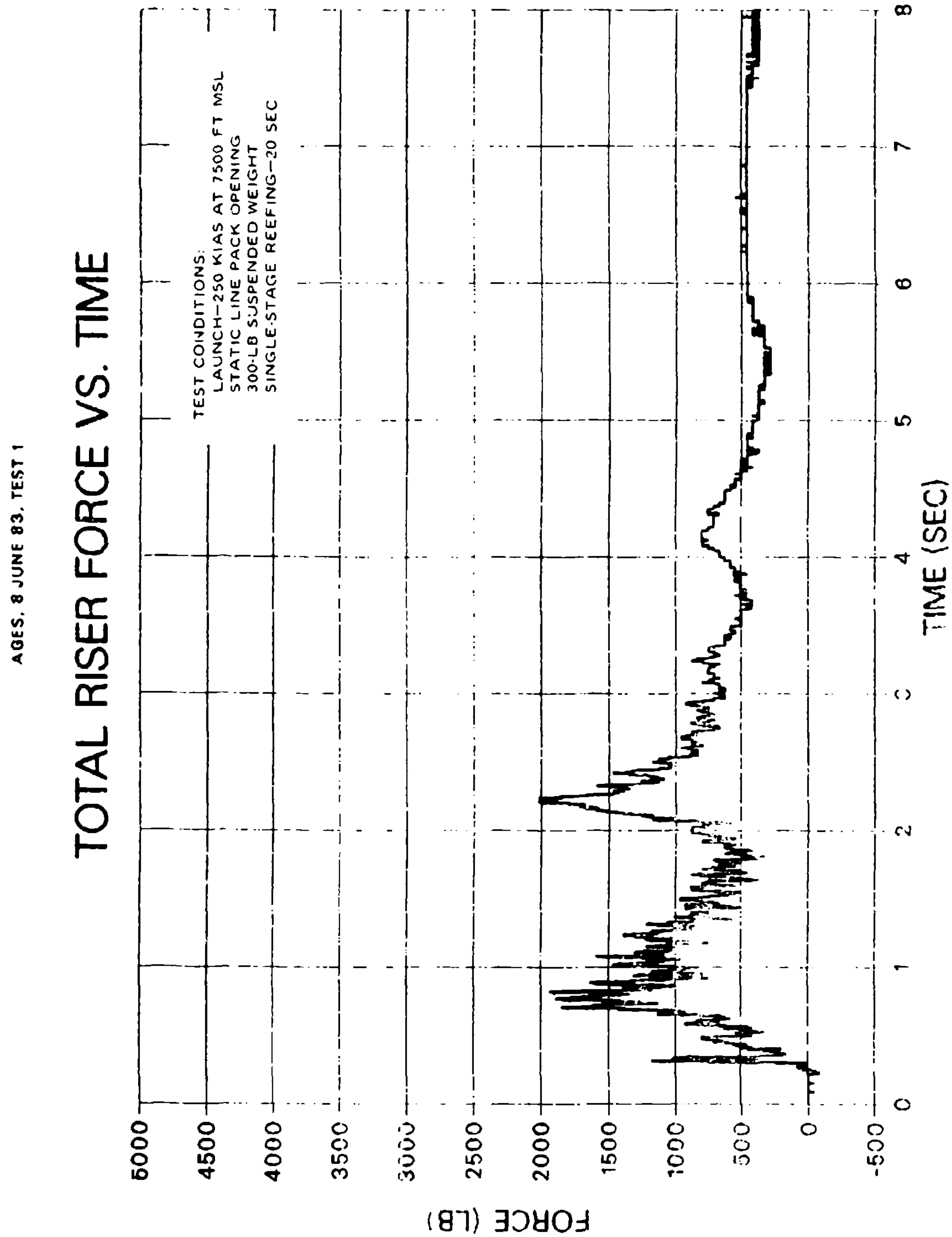
a. To be determined by higher authority.

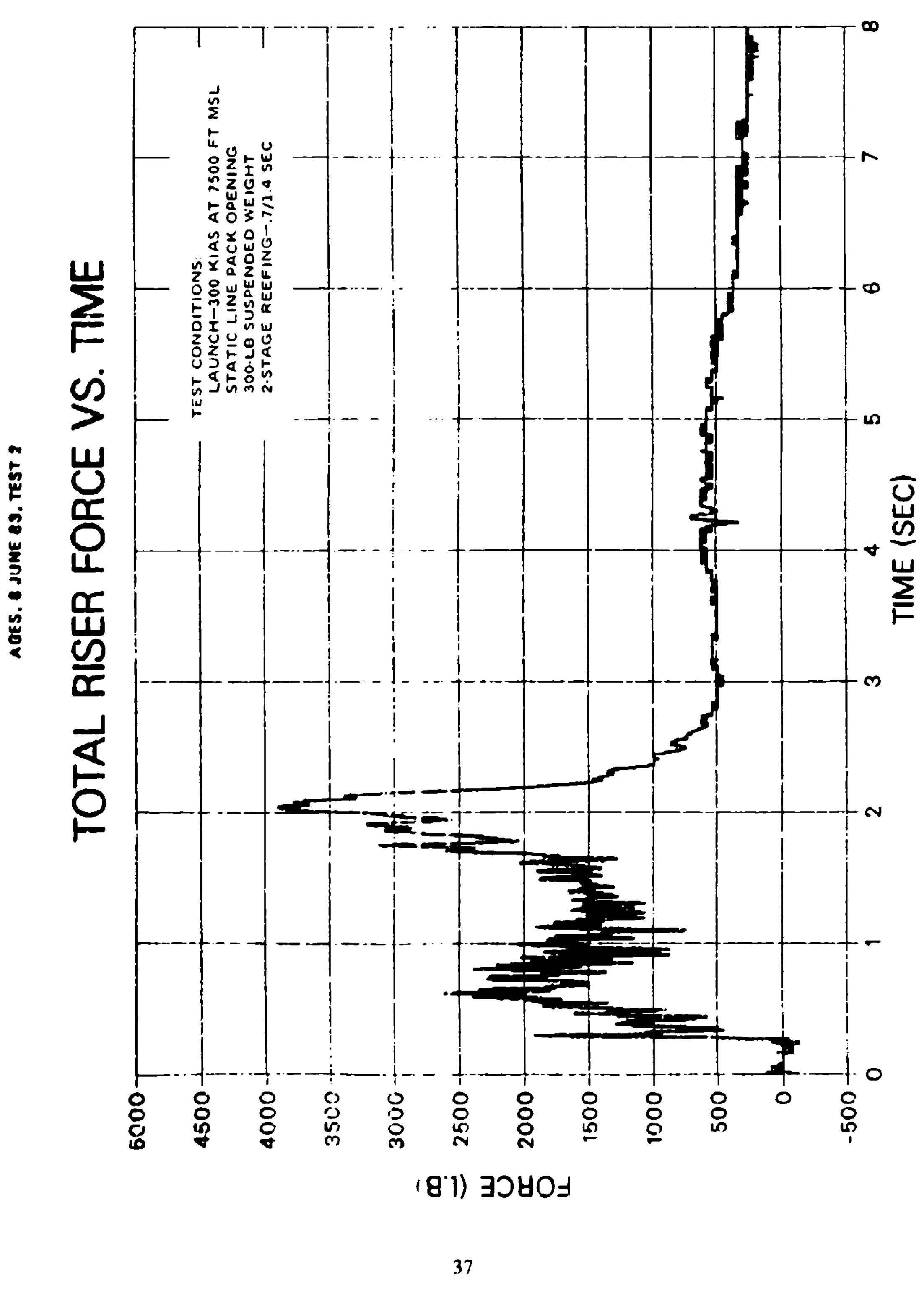
Appendix B

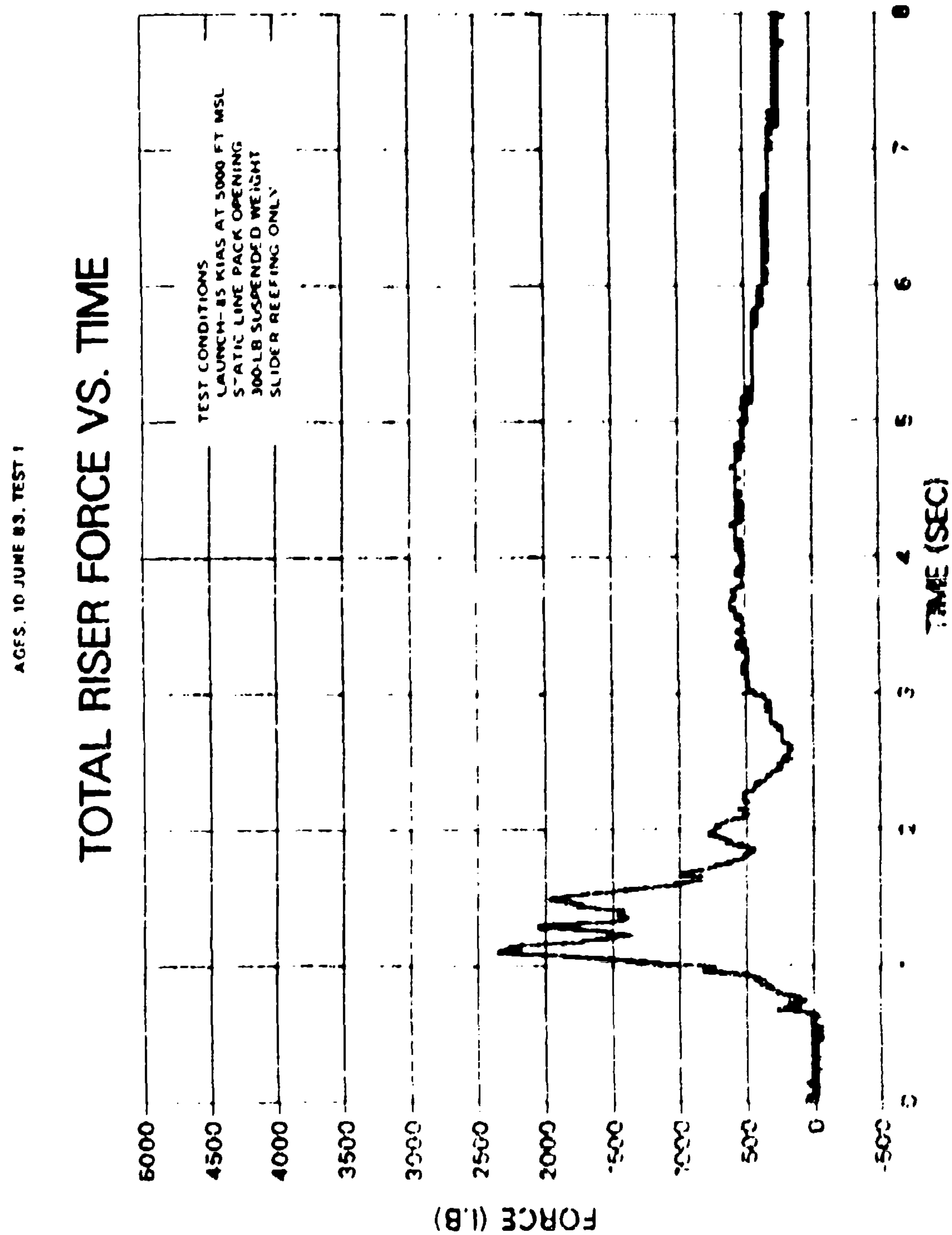
SAMPLE LOAD TRACES
AGES CONFIGURATION 13
TEST DATES 3 Jun, 8 Jun, 10 Jun 1983


AGES, 3 JUNE 83, TEST 3
TOTAL RISER FORCE VS. TIME
TEST CONDITIONS:
LAUNCH—250 KIAS AT 7500 FT MSL
.75-SEC ACTUATOR DELAY
300-LB SUSPENDED WEIGHT
2-STAGE REEFING—.7/1.4 SEC
FORCE (LB)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
TIME (SEC)
0
1
2
3
4
5
6
7
8


ABES, 3 JUNE 83, TEST 4
TOTAL RISER FORCE VS. TIME
TEST CONDITIONS:
LAUNCH—320 KIAS AT 15000 FT MSL
.75-SEC ACTUATOR DELAY
300-LB SUSPENDED WEIGHT
2-STAGE REEFING—1.0/2.0 SEC
FORCE (LB)
6000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
TIME (SEC)
0
1
2
3
4
5
6
7
8


AGES, 8 JUNE 83, TEST 1
TOTAL RISER FORCE VS. TIME
TEST CONDITIONS:
LAUNCH—250 KIAS AT 7500 FT MSL
STATIC LINE PACK OPENING
300-LB SUSPENDED WEIGHT
SINGLE-STAGE REEFING—20 SEC
FORCE (LB)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
TIME (SEC)
0
1
2
3
4
5
6
7
8


AGES, 8 JUNE 83, TEST 2
TOTAL RISER FORCE VS. TIME
TEST CONDITIONS:
LAUNCH—300 KIAS AT 7500 FT MSL
STATIC LINE PACK OPENING
300-LB SUSPENDED WEIGHT
2-STAGE REEFING—.7/1.4 SEC
FORCE (LB)
6000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
TIME (SEC)
0
1
2
3
4
5
6
7
8


AGES, 10 JUNE 83, TEST 1
TOTAL RISER FORCE VS. TIME
TEST CONDITIONS
LAUNCH—85 KIAS AT 5000 FT MSL
STATIC LINE PACK OPENING
300-LB SUSPENDED WEIGHT
SLIDER REEFING ONLY
FORCE (LB)
6000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
0
1
2
3
4
5
6
7
8
TIME (SEC)

INITIAL DISTRIBUTION

8 Naval Air Systems Command
  AIR-00D4 (2)
  AIR-310H (2)
  AIR-531 (4)
1 Chief of Naval Operations (OP-50C)
1 Chief of Naval Material (MAT-08D4)
2 Naval Sea Systems Command (SEA-99612)
1 Commander in Chief, U.S. Pacific Fleet (Code 325)
2 Marine Corps Development and Education Command, Quantico
1 Commander, Third Fleet, Pearl Harbor
1 Commander, Seventh Fleet, San Francisco
4 Naval Air Development Center, Warminster (Code 6032)
1 Naval Air Technical Training Center, Lakehurst
1 Naval Air Test Center, Patuxent River (Code SY-70)
3 Naval Ship Weapon Systems Engineering Station, Port Hueneme
  Code 5711, Repository (2)
  Code 5712 (1)
1 Pacific Missile Test Center, Point Mugu (Code 1131)
1 Naval War College, Newport
4 Army Research and Development Laboratories, Natick (DRDNA-UAS)
2 Army Troop Support and Aviation Materiel Readiness Command, St. Louis
2 Aeronautical Systems Division, Wright Patterson Air Force Base
  ASD/AEL (1)
  ASD/ENECA (1)
5 Air Force Flight Test Center, Edwards Air Force Base (6520th Test Group, TEEF)
1 San Antonio Air Logistics Center, Kelly Air Force Base (SA-ALC/MMIRC)
12 Defense Technical Information Center
1 Federal Aviation Administration (Standards Division, M/S 110)